Heliophysics Technology And Instrument Development For Science

# Development of a new Research Quality, Low-Cost Inductive Magnetometer for Heliophysics Missions

Completed Technology Project (2018 - 2021)

## Project Introduction

Science Goals and Objectives: A fundamental parameter of the Sun-Earth space environment is the magnetic field. The magnetic field of the Sun and Earth constrain the motion of the plasma and energetic particle environment, define different boundaries (shocks, discontinuities) and regions of the Sun-Earth system, and interact with the plasma environment through waves and magnetic reconnection to energize and interconnect the solar and terrestrial plasma environments. One of the NASA Heliophysics goals is to make simultaneous multi-point observations throughout the magnetosphere to understand global dynamics and structure. A magnetosphere constellation mission has been proposed to measure the structure of the Earth's magnetotail to determine the spatial scale of phenomena such as bursty bulk flows, reconnection sites, the general convection patterns in the plasma sheet, and magnetic structures such as flux rope plasmoids. Such a constellation mission in combination with MHD models provide the first ever global time evolving vector field and streamline images of the magnetotail. In order to meet these science objectives low-cost, low-volume, low-mass and low-power vector magnetometers are needed on each spacecraft. One idea to make this possible is to use relatively lower-sensitivity commercial sensors, but make up for their low sensitivity by making a large number of measurements throughout the system. This proposal takes a “have your cake and it eat too” approach, by developing a new type of Inductive Magnetometer that is much cheaper, smaller, and lower-power, but with the same research quality performance metrics of modern fluxgate magnetometers. These magnetometers will provide a distributed high-quality snapshot of the global magnetotail magnetic field that can be used to identify magnetotail regions and energy state, provide crucial observations of signatures of dynamic processes such as magnetic reconnection, flux rope formation and evolution, magnetic flux convection, and the ULF wave environment. The magnetic field strength provides the information needed for calculations of the particle phase space density, plasma Beta, and Alfvén speed. Because of its importance for understanding essentially all of the outstanding questions in space physics and its importance for space weather predictions, essentially all future NASA Heliophysics missions require a vector magnetometer so this instrument development proposal would have broad impact. Methodology: To address the science requirements of future Heliophysics missions and to enable large scale-constellation missions, this proposal has a goal of reducing the cost, mass, volume, and power of traditional fluxgate magnetometers by an order of magnitude over those currently flown while having equal or better precision, noise-level, linearity, and stability. The UM new digital induction magnetometer will be developed in the UM Magnetics Lab and the Space Physics Research Laboratory. The instrument does not use an A/D converter making it much more radiation tolerant than traditional fluxgate magnetometer designs. This proposal is a follow on to our previous H-TIDES project that improved and space environmentally tested a commercial magneto-inductive magnetometer from PNI. In the new induction


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## Organizational Responsibility

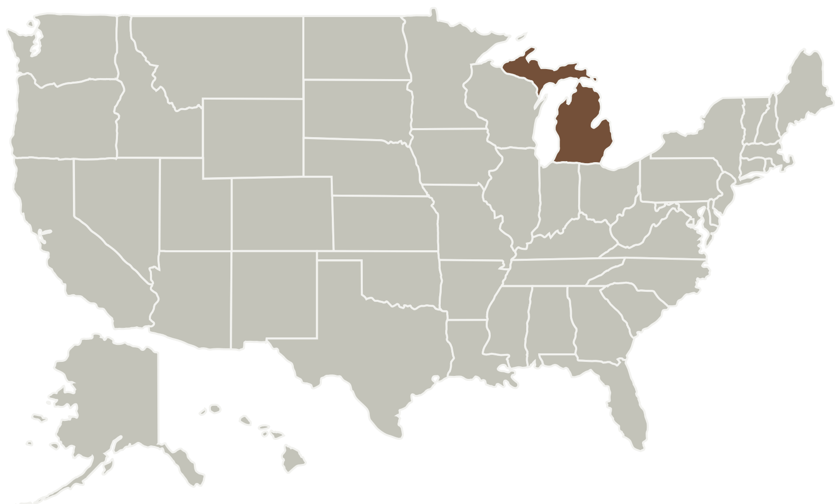
**Responsible Mission Directorate:**

Science Mission Directorate (SMD)

**Responsible Program:**

Heliophysics Technology and Instrument Development for Science magnetometer, the magnetic field is measured by counting the time between flips of the magnetic induction of the circuit, which is dependent on the strength of the applied DC field [Leuzinger and Taylor, 2010]. This new project develops a space-qualified instrument package based on the PNI design, but uses higher quality components, packaging and pairs with a processor that enables a stand alone system with order of magnitude improvement on the noise and sensitivity, but keeps the small package and low-power attributes in addition to keeping the single unit cost on the order of a few thousand dollars.

### Primary U.S. Work Locations and Key Partners



| Organizations Performing Work | Role | Type | Location |
|---|---|---|---|
| University of Michigan, College of Engineering | Supporting Organization | Academia | Michigan |
| University of Michigan-Ann Arbor | Supporting Organization | Academia | Ann Arbor, Michigan |

| Primary U.S. Work Locations |
|---|
| Michigan |

## Project Management

**Program Director:**
Roshanak Hakimzadeh

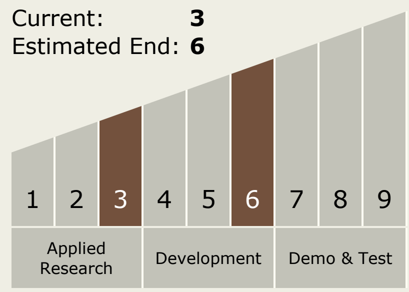
**Program Manager:**
Roshanak Hakimzadeh

**Principal Investigator:**
Mark Moldwin

**Co-Investigators:**
James W Cutler
Bret M Bronner
Leonardo H Regoli
Kathryn A Dewitt

## Technology Maturity (TRL)

Start: **3**
Current: **3**
Estimated End: **6**




## Technology Areas

**Primary:**

- TX08 Sensors and Instruments
  └ TX08.3 In-Situ Instruments and Sensors
    └ TX08.3.1 Field and Particle Detectors

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## Target Destination

The Sun